Editorial: Language Acquisition and Evolution

Language is often regarded as the hallmark for human intelligence. So, what *design features* make humans' linguistic behaviour so special? First, human language is largely symbolic, which means that the communicative signals have either an arbitrary relationship to their meaning or reference, or this relationship is conventionalised (Peirce, 1931–1958). As a result, the relationship between signal and reference must be learnt. Second, the number of words that make up a typical language is extremely large. There have been estimates that humans by the age of 18 have acquired approximately 60,000 words (Anglin, 1993). Third, the human vocal apparatus and auditory system allow us to produce and distinguish many different sounds, which we can combine in a controlled fashion to make even more distinctive vocalisations. Fourth, human language is an open system, so we can easily invent new words and communicate about previously unseen objects or events, thus allowing for language to grow and change. Finally, language has a complex grammar, which allows us to combine words in a different order and inflect words to give utterances different meanings. In effect, this allows humans to produce an infinite number of utterances given a finite number of means (Chomsky, 1956).

Clearly, many other species communicate as well and some of these have complex communication systems. Some bird songs, for instance, seem to have rather complex syntactic rules, but they seem to lack complex semantics, so their communication system cannot be considered symbolic. Vervet monkeys do have symbolic communication, but their communication system is not very complex in either size or structure. Communication among bees has some compositional structure, but – again – the size of their communication is very limited and their signals are more iconic than symbolic. Perhaps the most closely related forms of animal communication, with respect to human language, can be found in chimpanzees and other primates, as well as in parrots and dogs, that have been reared (and trained) in a human society. Still, although their communication systems go beyond those of conspecifics raised in the wild and other animals, the size and structural complexity are a far cry from human language.

In order to understand in more detail why human language is the way it is and why other species fail to arrive at similarly complex behaviour, it is important to understand its origins and evolution. Although the interest in language origins and evolution goes back to, at least, the ancient Greeks, research in this field has become 'booming business' since the seminal work of Pinker and Bloom in 1990. As language is such a striking feature of human behaviour, the field is highly interdisciplinary, attracting researchers from anthropology, archaeology, paleontology, biology, primatology, philosophy, linguistics, psychology, neuroscience and computer science. The role of computer science is to provide tools to test theories regarding the evolution of language. Such tools can be used to calculate predictions, which are difficult to achieve analytically. In addition, computational models allow us to do experiments that are otherwise impossible, such as changing the population dynamics or monitoring what is going on inside individuals. Recent collections from the field include various proceedings of the Evolution of Language conferences (Hurford, Knight, & Studdert-Kennedy, 1998; Knight, Studdert-Kennedy, & Hurford, 2000; Wray, 2002; Tallerman, 2005) and the edited volume by Christiansen and Kirby (2003). Cangelosi and Parisi (2002) have edited a clear and thorough introduction to the computational modelling of language evolution.

In a nutshell, what do we know about how language evolved? On the one hand, we know that humans, at least to some extent, must have adapted to use and acquire language. On the other hand, it seems that language itself has adapted to become learnable (Deacon, 1997). In the extreme, these views can be classified by the famous nature versus nurture debate, where the nativists believe that the underlying structure of language has evolved biologically into some innate Universal Grammar (Chomsky, 1956; Pinker & Bloom, 1990), while the 'nurturers' believe that there was no specific biological adaptation to language, which they claim is primarily learnt and has evolved culturally (Tomasello, 1999). Although the nature vs. nurture debate is still prominent, most researchers hold the more moderate view that language has evolved as a combination of biological and cultural adaptations.

[FIGURE 1 ABOUT HERE]

Kirby and Hurford (2002) have identified three adaptive systems, which interact with each other to account for language evolution, see Figure 1. These systems include *biological evolution*, *individual learning* and *cultural evolution*. In their view, biologically, we have evolved the capacity to acquire and use language. Using and learning language is done in a cultural setting. They claim that, since individuals typically do not acquire a language perfectly, learning a language gives rise to language change. More specifically, the language tends to change such that it can be learnt with more ease. This then leads to the formation of *language universals*, which in turn can give rise to further biological adaptations, thus closing the circle. Although we are still far from understanding the underlying principles of these adaptive systems, computational studies have provided some major insights, some of which are presented in this special issue.

The special issue

Much computational research has been done investigating how acquisition mechanisms could give rise to a cultural evolution of language (see, e.g., Cangelosi & Parisi, 2002; Briscoe, 2002; Kirby, 2002; Steels, 1997; Vogt, in press, for overviews). The realisation that language acquisition mechanisms are crucial to our understanding of language evolution inspired the organisation of a symposium on 'Language Evolution and Acquisition' at the Human Behavior and Evolution Society conference, held in Berlin in the summer of 2004. Based on this symposium, the decision was made to organise a special issue on this subject in Adaptive Behavior. Six papers have been accepted, which cover a wide perspective on language evolution and its acquisition.

The first theme that is covered relates to the evolution and acquisition of phonological structures and is presented in two papers. First, Pierre-Yves Oudeyer presents a model of the cultural evolution of syllable systems. Oudeyer shows how phonological structures can be selected culturally, such that the population in his model can acquire these structures with more ease. In essence, the paper shows how phonological aspects of language can form through self-organisation without the need for innate biases that specify the form of such structures. In the second paper, Bart de Boer supposes that complex speech must have evolved from initially holistic systems. Using a model based on evolutionary game theory and without specifying the exact mechanisms for producing speech sounds, de Boer investigates under what conditions biological evolution could have selected for the evolution of complex speech sounds.

The second theme revolves around the acquisition and evolution of mappings between words and meanings. Where the contribution by Tony Belpaeme and Joris Bleys investigates the emergence of universal tendencies in colour categories, Andrew Smith's paper focuses on specific language acquisition mechanisms that could have evolved to facilitate language acquisition and evolution. Belpaeme and Bleys start from recent studies that show that colour naming and linguistic colour categorisation exhibit universal tendencies across different languages and cultures. There exist many hypotheses for explaining these universal tendencies, and Belpaeme and Bleys test their alternative hypothesis that the universality of these colour categories can be explained based on linguistic (i.e. cultural) transmission, constrained by some universal biases. Smith's paper starts from the observation that novel words can have, logically speaking, an infinite number of meanings, and so acquiring a word-meaning mapping is a very hard problem (Quine, 1960). Despite this, humans are extremely proficient in acquiring word-meanings. Drawing on controversies in the literature on child language acquisition, Smith models an acquisition mechanism based on cross-situational learning and meaning inference. In particular, the paper shows how the agents in his model acquire the language of their parents imperfectly, thus leading to language change, but nevertheless remain viable at communicating effectively.

The third theme covers the emergence and evolution of grammatical structures in language. The two papers, one by Paul Vogt and one by Peter Ford Dominey, take different approaches in researching aspects of this phenomenon. Vogt shows how the creative productions of children can contribute to our understanding how grammatical structures could have evolved. Based on the iterated learning model (e.g., Kirby, 2002) and the language game model (Steels, 1996), Vogt compares a model of vertical transmission of language with variants where the language is transmitted more horizontally. The paper shows that compositional (i.e. grammatical) structures can emerge viably in horizontal models under conditions where vertical models fail. The final paper by Dominey investigates an evolutionary trajectory from acquiring sensorimotor sequences to acquiring grammatical structures. Based on a review of neuroscientific literature, Dominey argues that our ancestral pre-linguistic capability to learn sequences of sensorimotor behaviour could have been incorporated to learn and evolve grammar. Dominey presents and reviews a neurophysiologically plausible model (and variants thereof) that could acquire both realistic sensorimotor sequences and linguistic sequences.

All contributions fit nicely within the framework set out by Kirby and Hurford (2002). The papers by Oudeyer, Smith and Vogt show how iterations of language acquisition and transmission can change the language culturally. Oudeyer suggests that this change facilitated the ease of learning for subsequent generations. In a way, this can also be said about Vogt's model, but Vogt's paper concentrates on a pressure to acquire compositional structures by children when they need to communicate about previously unseen objects. Although Smith's model does not reveal any advantageous reasons for language change, his study indicates that through successive meaning inferences language can change without affecting success in communication.

In relation to this, Belpaeme and Bleys argue how a number of constraints can drive the emergence of universal tendencies in colour categories. These constraints include biological constraints on embodiment, ecological constraints on the categorisation task and the environment, and communicative constraints that couple the category formation to language acquisition and transmission.

The contributions by de Boer and Dominey investigate how biological adaptations can facilitate the emergence of complex sequential structures in language. De Boer showed that memory limitations can lead to adaptations that favour the storage and use of combinatorial phonological structures over holistic storage. Dominey's study suggest that our ancestral pre-linguistic capability to learn sequences of sensorimotor behaviour could have been incorporated to learn and evolve grammar. Hence, the biological adaptation to facilitate the acquisition and use of complex language may have been minimal.

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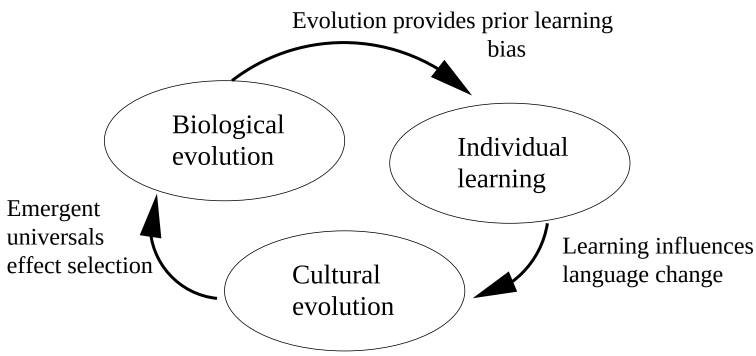

Figure 1: The interaction between three adaptive systems influencing the evolution of language. Adapted from Kirby and Hurford (2002).